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U.S. Labor supply and demand in the long run

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Abstract

In this paper we model U.S. labor supply and demand over the next 25 years. Despite the anticipated aging of the population, moderate population growth will provide growing supplies of labor well into the 21st century. Improvements in labor quality due to greater education and experience will also continue for some time, but will eventually disappear. Productivity growth for the U.S. economy will be below long-term historical averages, but labor-using technical change will be a stimulus to the growth of labor demand. Year-to-year changes in economic activity will be primarily the consequence of capital accumulation. However, the driving forces of economic growth over the long term will be demography and technology.

Keywords: Labor supply; Labor demand; Household preferences; Demographic transition

1. Introduction

In this paper, we model U.S. labor supply and demand in considerable detail in order to capture the enormous heterogeneity of the labor force and its evolution over the next 25 years. We represent labor supplies for a large number of demographic groups as responses to prices of leisure and consumption of goods and services. The price of leisure is an after-tax wage rate, while the prices of goods and services reflect the supply prices of the industries that produce them. By including demographic characteristics among the determinants of household preferences, we

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incorporate the expected demographic transition into our long-run projections of the U.S. labor market.

The U.S. population will be growing older and elderly households have very different patterns of labor supply and consumption. Our projections thus incorporate the expected fall in the supply of labor per capita. These changes in labor supply patterns are the consequence of population aging, rather than wage and income effects. Despite the anticipated aging of the U.S. population, moderate population growth will provide growing supplies of labor well into the 21st century. Improvements in the quality of U.S. labor input, defined as increased average levels of educational attainment and experience, will also continue for some time, but will gradually disappear over the next quarter century.

We represent labor demand for each of 35 industrial sectors of the U.S. economy as a response to the prices of productive inputs: labor, capital, and intermediate goods and services. In addition, labor demand is driven by changes in technology. Technical change generates productivity growth within each industry. Rates of productivity growth differ widely among industries, ranging from the blistering pace of advance in computers and electronic components to the gradual decline in construction and petroleum refining. In addition, changes in technology may be biased. Labor-saving technical change reduces demand for labor for given input prices, while labor-using change increases labor demand.

Productivity growth for the U.S. economy as a whole will be below long-term historical averages. However, productivity growth in information technology equipment and software will continue to outpace productivity growth in the rest of the economy. The output of the U.S. economy will continue to shift toward industries with high rates of productivity growth. Labor input biases of technical change are substantial in many industries. Labor-using, rather than labor-saving, biases predominate. Labor-using technical change will continue to be a stimulus to the growth of labor demand and differences in the biases for different industries will play an important role in the reallocation of labor.

We incorporate the determinants of long-term labor supply and demand into a model of U.S. economic growth. We refer to this model as IGEM[1] for Inter-temporal General Equilibrium Model. Markets for labor, capital, and the output of the economy equilibrate through the price system at each point of time. In the labor market, for example, wage rates determine the labor supplied by the current population and the labor demanded by employers in the many sectors of the economy. In the model and the U.S. economy year-to-year changes in the level of economic activity are primarily the consequence of the accumulation of capital. However, over a quarter century the driving forces of economic growth are demography and technology—as encapsulated in the neo-classical theory of economic growth.

In IGEM, capital formation is determined by the equilibration of saving and investment. We model household saving at the level of the individual household. Consumption, labor supply, and saving for each household are chosen to maximize a utility function, defined on the stream of future consumption of goods and leisure, subject to an inter-temporal budget constraint. The forward-looking character of savings decisions allows changes in future prices and rates of return to affect current labor supply. The availability of capital input in the U.S. economy is the consequence of past investment. This backward-looking feature of capital accumulation links current markets of capital input to past investment decisions.

[1] Detailed information about earlier versions of IGEM and a survey of applications are available in Jorgenson (1998).

Table 1
Personal consumption expenditures and leisure, IGEM categories, 2000

	IGEM categories	$Bil	Category
1	Food	568.6	3
2	Meals	376.5	4
3	Meals-employees	9.9	5, 6
4	Shoes	46.3	12
5	Clothing	267.4	14–16
6	Gasoline	164.4	75
7	Coal	0.2	40
8	Fuel oil	17.9	40
9	Tobacco	72.2	7
10	Cleaning supplies	115.8	21, 34
11	Furnishings	38.3	33
12	Drugs	156.3	45
13	Toys	62.7	89
14	Stationery	23.4	35
15	Imports (travel)	3.3	111
16	Reading	51.7	88, 95
17	Rental	247.4	25, 27
18	Electricity	101.5	37
19	Gas	40.8	38
20	Water	48.8	39
21	Communications	130.6	41
22	Domestic service	16.0	42
23	Other household	48.5	43
24	Own transportation	210.8	74, 76, 77
25	Transportation	56.9	79, 80, 82–85
26	Medical services	921.3	47–49, 51, 55
27	Health Insurance	70.6	56
28	Personal services	76.2	17, 19, 22
29	Financial services	517.7	61–64
30	Other services	114.8	65–67
31	Recreation	255.5	94, 97–103
32	Education and welfare	354.1	105–108
33	Foreign travel	80.9	110
34	Owner maintenance	90.0	Our imputation
35	Durables flow	1394.4	Our imputation
	Leisure	13786.3	Our imputation

Note: NIPA-PCE category refers to the line number in Table 2.4 of SBC 2002.

2. A long-run model of the U.S. economy and the labor market

Our household model generates demands for a detailed list of personal consumption expenditures given in Table 1. Household preferences are structured in a nested, or tiered, manner. At the top tier utility is a function of non-durables, capital services, consumer services, and leisure. Lower tiers allocate non-durables to specific goods, like food and clothing, and consumer services to transportation, finance and other services. Household consumption patterns for goods and leisure are derived from the Consumer Expenditure Survey (CEX).[2] The items in Table 1 are

[2] See http://www.bls.gov/cex/home.htm. Detailed documentation for the CEX is available at: http://www.bls.gov/cex/home.htm#publications.

Table 2
Industry output and value added, 2000

Code	Industry name	Output	Value-added	SIC
1	Agriculture	388,994	195,781	01–02, 07–09
2	Metal mining	15,603	7,167	10
3	Coal mining	23,081	14,175	11–12
4	Petroleum and gas	136,651	72,669	13
5	Non-metallic mining	18,894	10,619	14
6	Construction	995,279	419,200	15–17
7	Food products	487,587	156,127	20
8	Tobacco	35,853	10,108	21
9	Textile mill products	61,629	21,811	22
10	Apparel and textiles	84,273	32,899	23
11	Lumber and wood	115,974	43,305	24
12	Furniture and fixtures	87,965	39,619	25
13	Paper products	175,955	72,942	26
14	Printing and publishing	233,523	137,723	27
15	Chemicals products	422,655	183,438	28
16	Petroleum refining	235,145	26,422	29
17	Rubber and plastic	170,270	77,459	30
18	Leather products	10,616	4,028	31
19	Stone, clay and glass	111,040	53,522	32
20	Primary metals	190,627	59,691	33
21	Fabricated metal	279,540	125,540	34
22	Industrial machinery and equipment	472,251	193,646	35
23	Electronic and electric equipment	433,257	195,913	36
24	Motor vehicles	427,709	83,072	371
25	Other transportation equipment	186,241	87,121	372–379
26	Instruments	183,293	104,351	38
27	Miscellaneous manufacturing	52,715	21,889	39
28	Transport and warehouse	553,535	263,335	40–47
29	Communications	430,330	231,027	48
30	Electric utilities	245,950	166,618	491, %493
31	Gas utilities	81,196	26,421	492, %493, 496
32	Trade	1,965,715	1,187,180	50–59
33	FIRE	2,009,429	1,240,039	60–67
34	Services	3,455,269	2,197,343	70–87, 494–495
35	Government enterprises	256,268	167,722	
36	Private households	1,394,410	1,394,410	88
37	General government	1,194,160	1,194,160	

based on the consumption categories in the National Income and Product Accounts (NIPAs).[3] They are linked to the supplying industries listed in Table 2.

As the owner of the economy's wealth, the household sector makes a second contribution to the demand side of the economy through the demand for investment goods. The savings by the household sector are allocated between domestic and foreign investment and the domestic portion is distributed among investments in assets such as structures, equipment, consumer durables and inventories. Capital stocks and capital services are derived primarily from the Fixed Asset

[3] See http://www.bea.gov/national/index.htm. Detailed documentation for the NIPAs is available at: http://www.bea.gov/methodologies/index.htm.

Accounts of the Bureau of Economic Analysis,[4] which include information on investment by 60 asset categories. Data on labor input by industry are derived from detailed demographic and wage data in the annual Current Population Surveys and the decennial Censuses of Population, as described by Jorgenson, Ho, and Stiroh (2005).

We separate the production sector in IGEM into 35 individual industries. The complete list is given in Table 2, together with the value of each industry's output in 2000 and the corresponding Standard Industrial Classification codes. Each industry produces output from labor, capital, and intermediate inputs, using a technology that allows for substitution among these inputs. Although technology can be represented by means of a production function, we find it much more convenient to use a dual approach, based on a price function that gives the price of output of each sector as a function of the prices of inputs. Technologies are structured in a nested or tiered manner with intermediate inputs divided between energy and materials; both energy and materials are further sub-divided among inputs that correspond to the 35 commodity groups produced by the 35 industries.

Our representation of the technology in each sector includes the rate and biases of technical change. The rate of technical change captures improvements in productivity or growth in output per unit of input. The biases of technical change correspond to increases or decreases in the shares of inputs in the value of output, holding input prices constant. The evolution of patterns of production reflects both price-induced substitution among inputs and the impact of changes in technology. We project the historical patterns of technical change represented in our database in order to incorporate future changes in technology into the demand for inputs of labor, capital, and intermediate goods and services.

The production of each commodity by one or more of the 35 U.S. domestic industries is augmented by imports of that commodity from the rest of the world to generate the U.S. domestic supply. This supply is allocated to U.S. industries as an intermediate input and to final demand for consumption by U.S. households and governments, investments by U.S. businesses, households, and governments, and net exports. Since imports are not perfect substitutes for commodities produced domestically, we also model the substitution between imports and domestic production explicitly. The rest of the world absorbs exports from the U.S. and the net flow of resources in each period is governed by an exogenously specified current account deficit.

The final sector explicitly considered in our model is the government sector, which taxes, spends, and makes transfer payments. Public consumption is one component of final demand, while public borrowing is one of the uses of private saving. The flow of goods and factors among the four sectors of the U.S. economy – business, household, government and the rest of the world – is illustrated in Fig. 1. Prices adjust to equate the supply from domestic and foreign producers to the demand from households, investors, government, and exports in each period.

Our model of the U.S. economy is implemented econometrically. Parameters describing the behavior of producers and consumers are estimated statistically from a data set that we have constructed specifically for this purpose. These data are based on a new system of national accounts that integrates the wealth accounts with the National Income and Product Accounts (NIPAs).[5] The capital accounts include investment goods, capital services, capital stocks, and the corresponding prices. These data are described in detail by Jorgenson, Ho, and Stiroh (2005).

[4] See http://www.bea.gov/national/index.htm#fixed. Detailed documentation for the Fixed Assets Accounts is available at: http://www.bea.gov/methodologies/index.htm.

[5] See Jorgenson and Landefeld (2006).

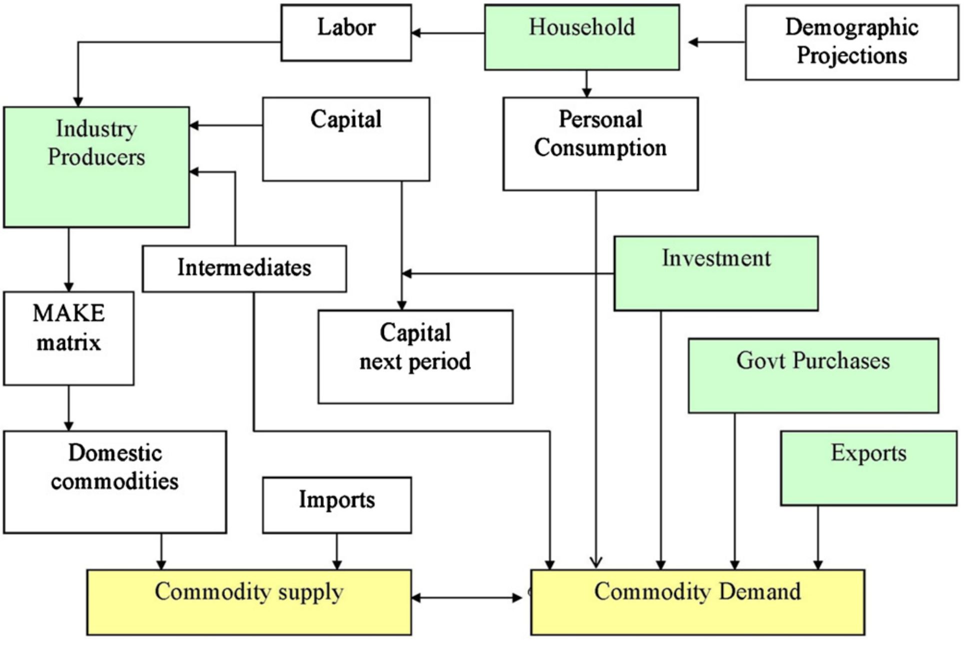

Fig. 1. Flow of goods and factors in IGEM.

Similar data have recently been released for members of the European Union by the EU KLEMS project.[6]

3. Exogenous variables in the projections

Our model of the U.S. economy simulates the future growth and structure of the economy over the intermediate term of 25 years. The time path of model outcomes is conditional on projections of exogenous variables. Among the most important of these variables are the total population, the time endowment of the working-age population, the overall government deficit, the current account deficit, world prices and government tax policies. Many of these are developed from published sources, "official" and otherwise. In addition, we project the evolution of technology in each of the 35 industries that make up the production sector of the model. These variables are projected from the historical data set that underlies the production model and its estimation.

The key exogenous variables that describe the growth and composition of the U.S. population are population projections by sex and individual year of age from the U.S. Bureau of the Census.[7] During the sample period the population is allocated to educational attainment categories using data from the Current Population Survey[8] in a way that is parallel to our calculation of labor

[6] See http://www.euklems.net/. This data set was released on 15 March 2007, and is described in "Use IT or Lose It," *The Economist*, May 19–25, 2007, p. 82.

[7] See: http://www.census.gov/popest/estimates.php. Historical data are taken from: http://www.census.gov/popest/archives/. These population data are revised to match the latest censuses (e.g., 1981 data is revised to be consistent with the 1990 Census).

[8] See http://www.census.gov/cps/.

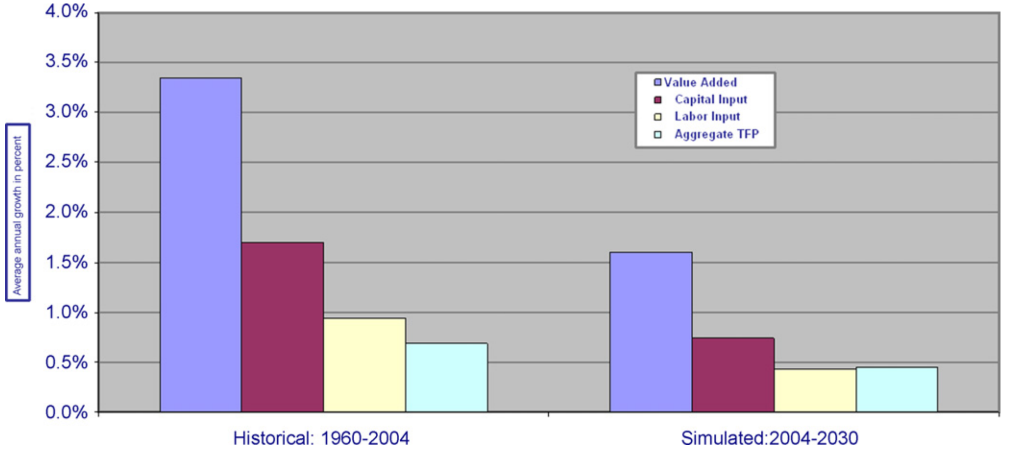

Fig. 2. Sources of growth.

input. Each adult is given a time endowment of 14 h a day to be used for work and leisure. The number of hours for each sex–age–education category is weighted by labor compensation rates and aggregated to form the national time endowment presented in Fig. 2.

Our projections use Census Bureau forecasts by sex and age. We assume that the educational attainment of those aged 35 or younger will be the same as in the last year of the sample period; that is, a person who becomes 22 years old in 2014 will have the same chance of having a BA degree as a person in 2004. Those aged 55 and over carry their education attainment with them as they age; that is, the educational distribution of 70 year olds in 2014 is the same as that of 60 year olds in 2004. Those between 35 and 55 have a complex adjustment that is a mixture of these two assumptions to allow a smooth improvement of educational attainment that is consistent with the observed profile in 2004. The result of these calculations, shown in Fig. 2, is that the U.S. population is expected to grow at just under 1% per year through 2030, reaching a level in excess of 365 million. The gradually slowing improvement in the average level of educational attainment implies that the time endowment grows at a modestly faster rate of around 1% through 2030.

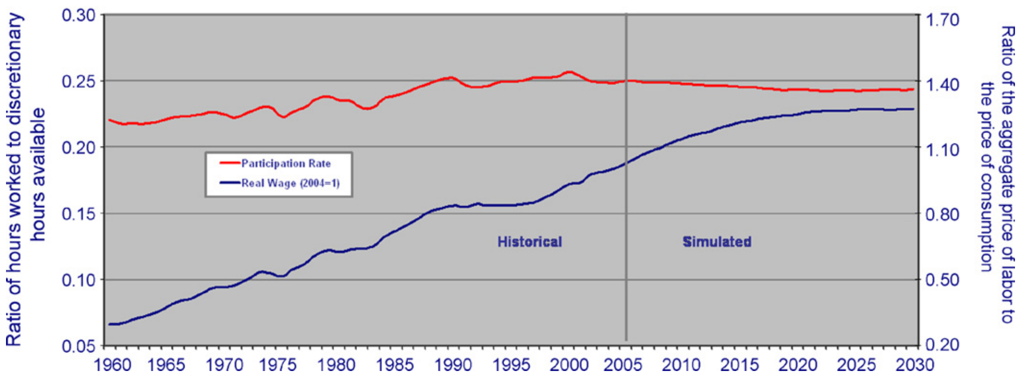

Fig. 3. Labor participation and real wages.

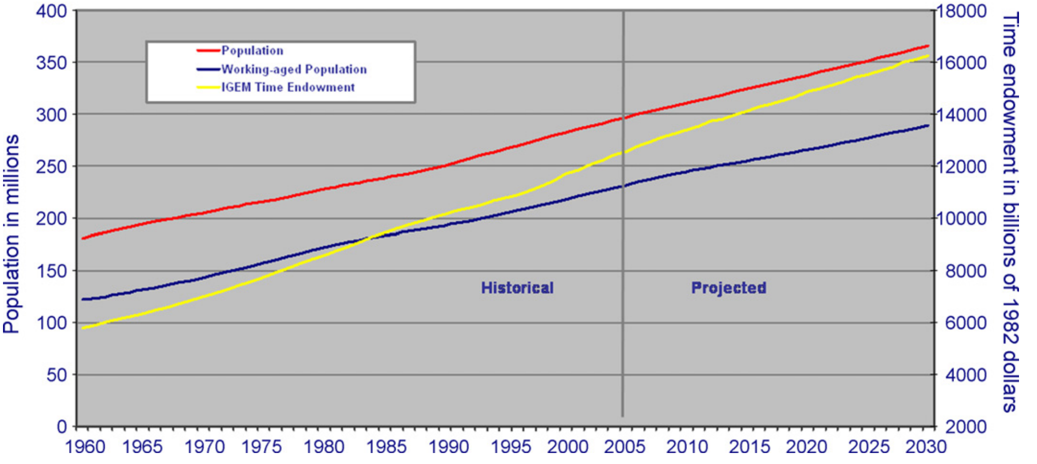

Fig. 4. Population and household time endowment.

We project productivity growth for each of the 35 industries, using the state-space approach of Jin and Jorgenson (2007). To illustrate this approach, Fig. 3 gives historical data for the period 1960–2004, based on the estimates of Jorgenson, Ho, Samuels, and Stiroh (2007). These data update and revise the estimates of Jorgenson, Ho, and Stiroh (2005). Fig. 4 presents projections of productivity growth for the period 2004–2030, using the state-space approach. Positive productivity growth reduces output prices, relative to costs of inputs, while negative growth raises output prices relative to costs.

For 2004–2030 our baseline projections reveal steadily improving productivity in 30 of the 35 sectors in IGEM. Electrical Machinery, which contains electronic components such as the semiconductor devices used in computers and telecommunications equipment, leads the list in projected productivity growth. Although the projected productivity growth rate exceeds 3%, this represents a slight reduction in the rate of productivity growth of just under 4% for the historical period 1960–2004. Non-electrical Machinery, including computers, has the second highest rate of productivity growth in both the historical period and the projections, but the projected growth rate is considerably lower than the historical rate.

We show below that the overall rates of productivity growth projected for the U.S. economy are substantially below the historical period 1960–2004. It is also important to recognize losses in productivity as well as gains at the industry level. There are several sectors with negative projected productivity growth, including the very large construction industry and the relatively small tobacco industry. Both industries also have declining productivity during the sample period 1960–2004.

Projections of the input biases are accomplished in a similar manner to projections of productivity. Fig. 5 gives historical data for the period 1960–2004, while Fig. 6 gives our projections for the period 2004–2030. We recall that the definition of biased technical change is the effect of changes in technology on the share of labor input in the value of industry output, holding prices of labor input, as well as capital, energy, and materials inputs constant. It is important to keep in mind that we have fitted and projected biases of technical change for capital, energy, and materials inputs, as well as labor input, but these are not presented in this paper in order to economize on space.

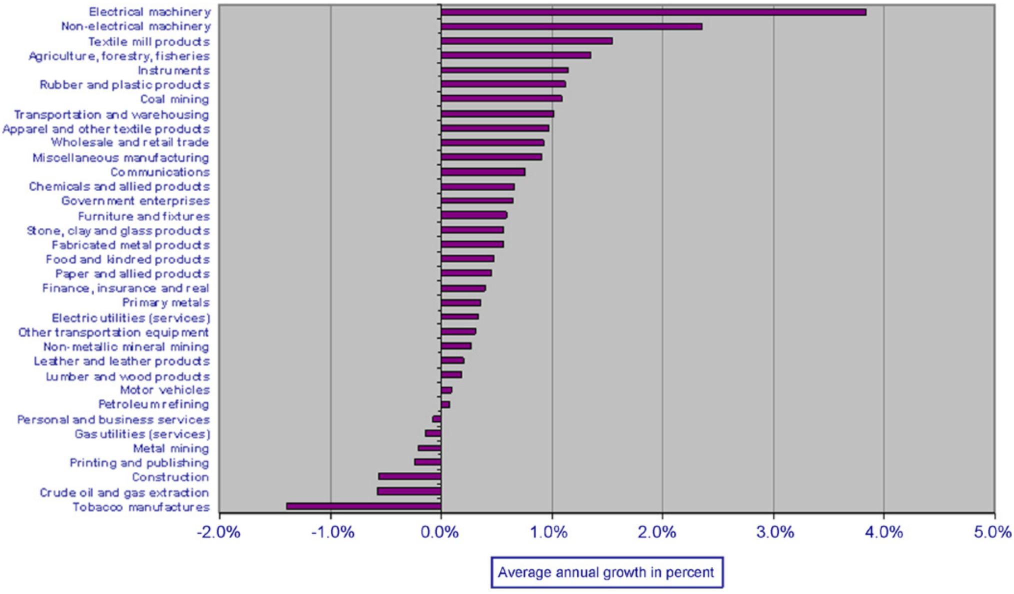

Fig. 5. Growth in total factor productivity, 1960–2004.

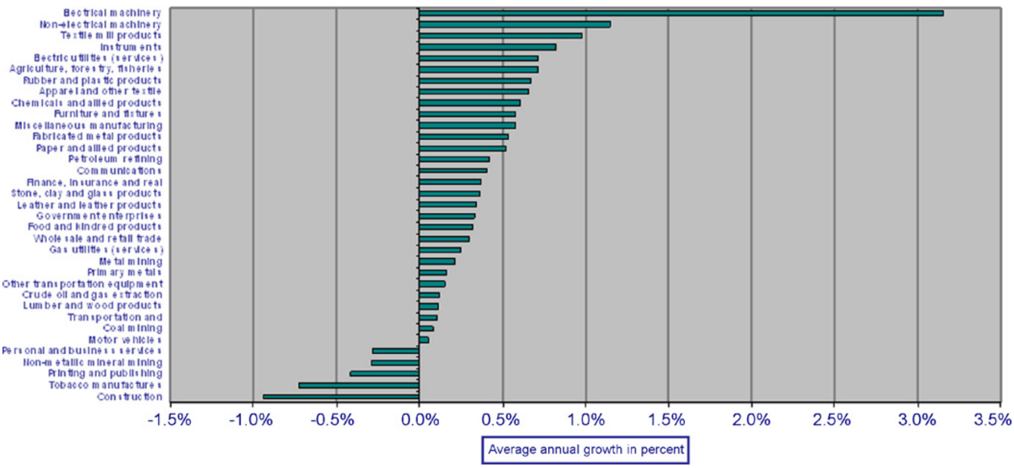

Fig. 6. Growth in total factor productivity, 2004–2030.

During the sample period technical change is predominantly labor-using rather than labor-saving. Metal mining, a relatively small industry, has a very large labor-using bias of technical change, while coal mining has a large labor-saving bias. Biases of technical change differ substantially among industries and both labor-using and labor-saving changes occur with some frequency. It is important to project rates of technical change to determine the growth rate of individual industries and the economy as a whole.

However, it is also important to project biases of technical change in order to capture the impact of changes in technology on the distribution of labor input among sectors.

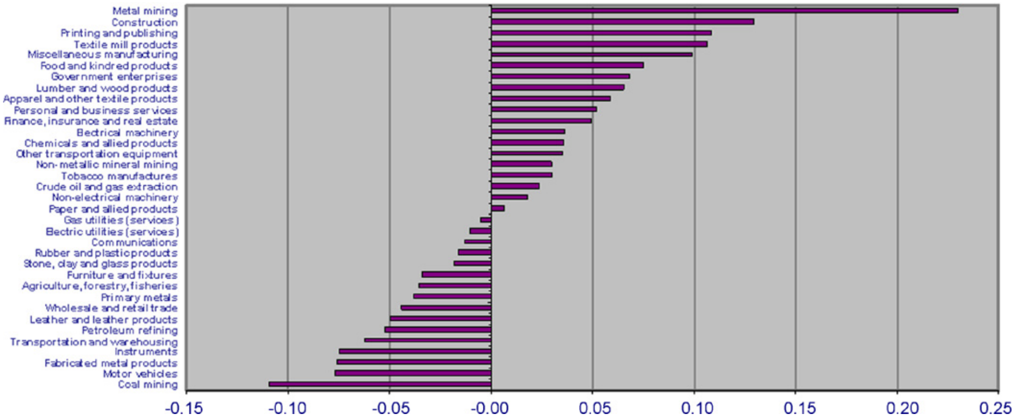

Fig. 7. Labor input biases, 1960–2004.

Two other important assumptions that determine the shape of the economy are the government and trade deficits. Our projection of the government deficit follows the forecasts of the Congressional Budget Office for the next 10 years and then is set on course to a zero balance by 2030.[9] The current account deficit is assumed to shrink steadily, relative to the GDP, so that it also reaches a sustainable balance by 2030. These simplifying assumptions allow the simulation the produce a smooth time path. The government and current account deficits are determinants of long run growth to the extent that they influence capital formation, but are substantially less important than the exogenous demographic and technology variables we have described.

4. Projection of U.S. economic growth

Our baseline path for the economy generates a labor force participation rate, defined as the ratio of labor input to the time endowment. We have used this to extrapolate the ratio of hours worked to discretionary hours available from the working age population. The participation rate presented in Fig. 7 reached a peak in 2000, before the shallow recession of 2001 and the "jobless" recovery that followed. The historical data from 1960 to 1990 show substantial gains in participation. No such gains in participation are in prospect for the next quarter century. At the same time, projections beginning in 2004 do not suggest a large decline in labor force participation.

It is important to keep in mind that the rate of population growth will be declining throughout the projection period 2004–2030. The working age population will be growing at a very similar rate to the population as a whole during our projection period. During the historical period 1960–2004 the working age population grew considerably more rapidly than the population. Finally, the time endowment, which adjusts the population for changes in composition by educational attainment and experience, will continue to grow more rapidly than the working age population. However, changes in composition will gradually disappear as average levels of education and experience stabilize.

Real wages, defined as the ratio of the price of labor input to the price of consumption goods and services, are also presented in Fig. 7. Contrary to historical trends often described in the business

[9] See http://www.cbo.gov/showdoc.cfm.

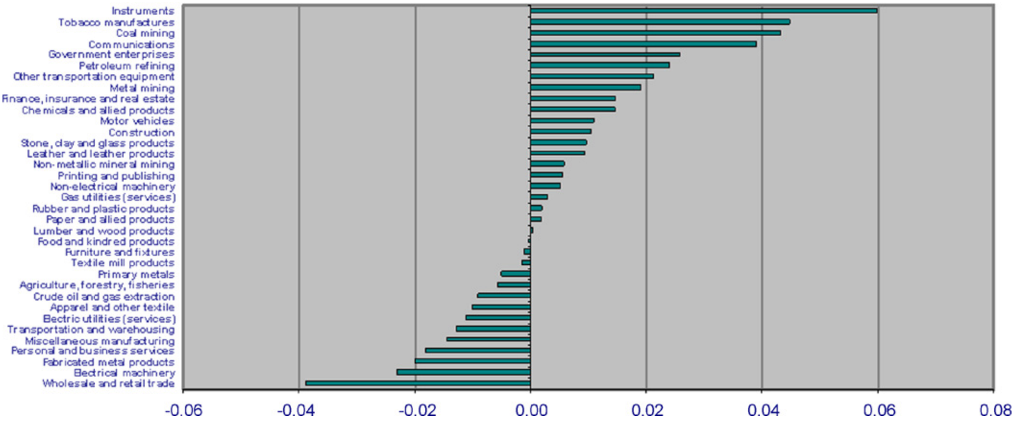

Fig. 8. Labor input biases, 2004–2030.

press, real wages have risen steadily throughout the post-war period with especially rapid growth rates during the period 1995–2004. Our projections of real wages rise steadily during the period 2004–2030, but at a decreasing rate. This declining rate of increase mimics the historical data from 1973–1995, prior to the U.S. growth resurgence. This began around 1995 and continued into the period 2000–2004. The slowdown of the rate of growth of real wages will occur despite the continuation of historical productivity trends summarized in Section 3.

We next turn to the sources of U.S. economic growth during the historical and projection periods. Fig. 8 presents historical data on the sources of U.S. economic growth during 1960–2004 recently compiled by Jorgenson, Ho, Samuels, and Stiroh (2007). The overall rate of growth is an impressive 3.34% per year. The most important source of growth is capital input, which contributes 1.70% or well over half of growth during the historical period. The next most important source of growth is labor input, which contributes 0.95% per year. These contributions are the growth rates of capital and labor inputs, each weighted by the corresponding share in the value of output. Total factor productivity growth contributes 0.69% per year or slightly more than 20% of growth during the historical period.

We project the growth of the U.S. economy during the period 2004–2030 to be only 1.61% per year. The contribution of capital input will remain the most important source of growth at 0.74% per year. The growth of total factor productivity will decline very slightly to 0.44% per year and will outstrip the sharply lower contribution of labor input of 0.42%. While the contributions of capital and labor inputs will still greatly predominate among the sources of U.S. economic growth, the relative importance of total factor productivity growth will jump substantially. This reflects the strength of the projected productivity trends described in Section 3.

We conclude our discussion of projected U.S. economic growth with a description of the growth of output and labor input at the industry level. Fig. 9 presents growth rates of labor input for each of the 35 industries in IGEM during the historical period 1960–2004. Slightly less than half the industries experienced an increase in labor input, led by Personal and Business Services. However, many industries experienced sharp declines in labor input, led by Leather and Leather Products, Apparel and Textile Products, and Gas Utilities. The growth rate of labor input overall was 1.64% per year.

We have projected a substantial slowdown in the growth rate of labor input for the period 2004–2030 to 0.70% per year. Fig. 10 provides a breakdown by industries.

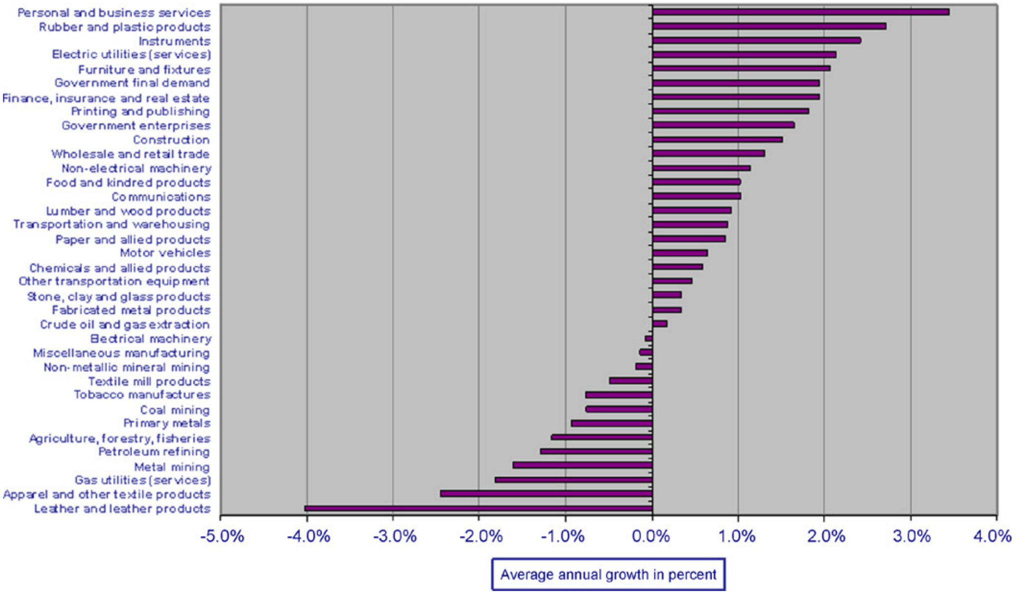

Fig. 9. Growth in labor input, 1960–2004.

Positive growth in labor input predominates in the projections. Relatively small sectors with low projected productivity growth like Tobacco and Petroleum Refining will show substantial increases in labor input. As widely anticipated, the large service sectors like Finance, Insurance, and Real Estate, will greatly predominate in the growth of labor input. Primary Metals and Metal Mining will continue to release labor input to a future U.S. economy that is increasingly constrained by the slow growth of the labor supply.

Labor input biases are an important component of changes in demand for labor input. Labor-using technical change results in an increase in the share of labor input, holding prices of labor,

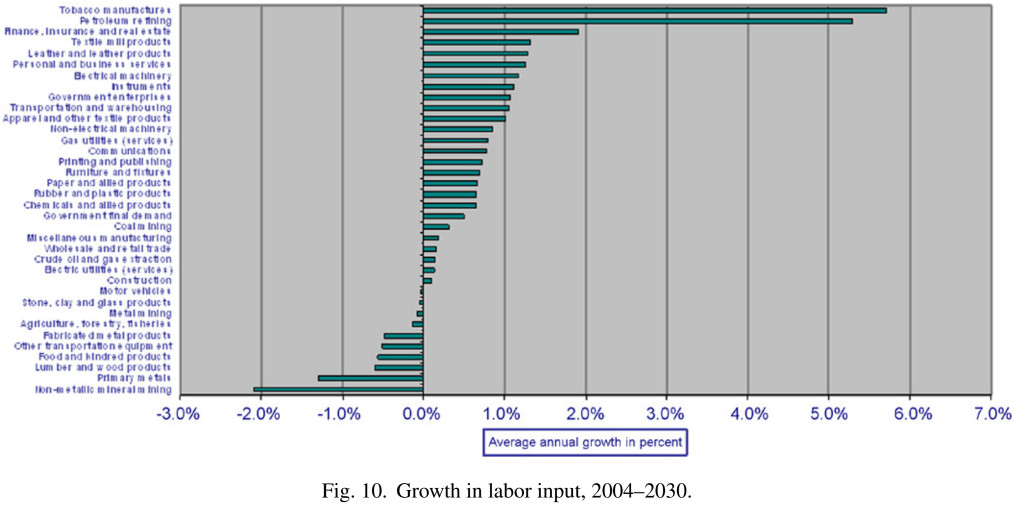

Fig. 10. Growth in labor input, 2004–2030.

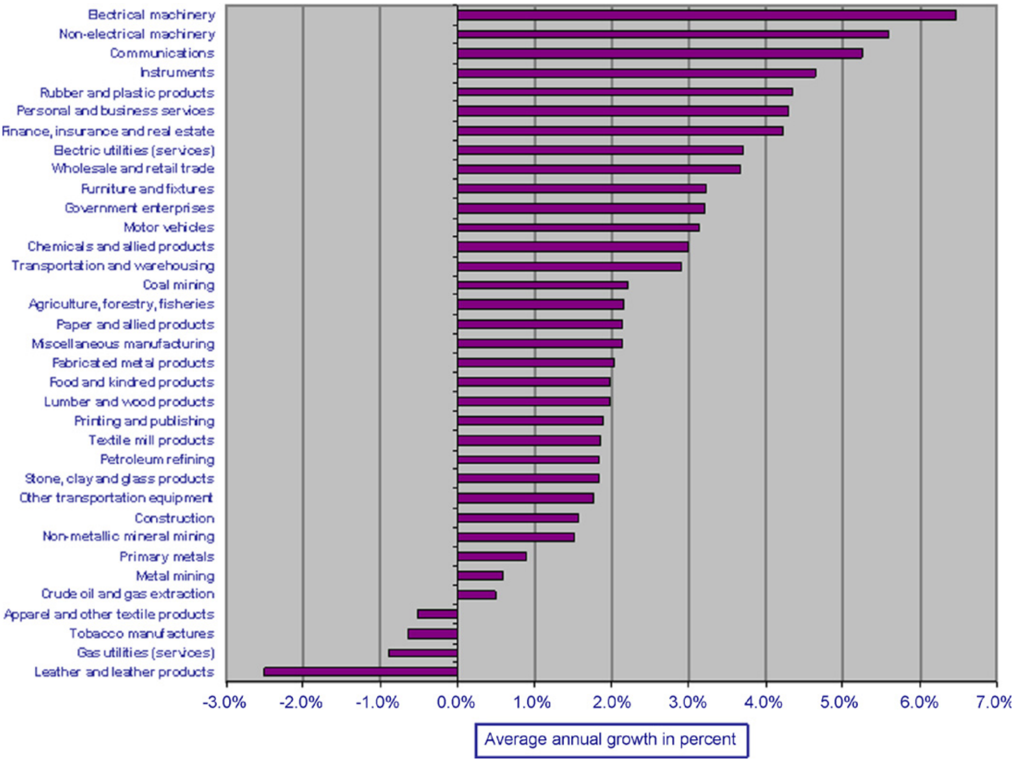

Fig. 11. Growth of domestic output, 1960–2004.

capital, energy, and materials inputs constant. This predominates in our projections, as well as in the sample period. The share of labor input in Instruments will increase by 0.06 during the projection period 2004–2030, reversing a similar decline in the share of labor input during the sample period 1960–2004. Metal mining, a small sector that had a large labor-using bias of

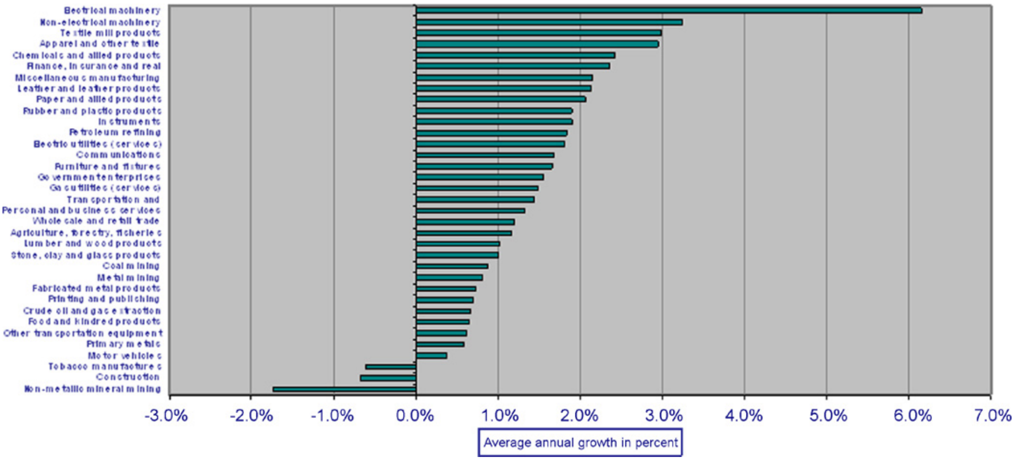

Fig. 12. Growth of domestic output, 2004–2030.

technical change during the sample period, has a smaller labor-using bias during the projection period. Biases of technical change are an important component of labor input demand, along with the steady rise in the price of labor input relative to other inputs.

Growth in industry output completes our picture of future U.S. economic growth. Fig. 11 gives historical data on output growth for the period 1960–2004. Economic growth during the period 1960–2004 differed widely among industries with a relatively narrow range of industries exceeding the economy-wide average of 3.22%. As expected, the rapidly growing sectors were led by Electrical Machinery, including electronic components. Substantial growth also took place in Non-electrical Machinery, which contains computers, Communications, the largest consuming sector for information technology equipment and software, and Instruments, another major consumer. Only three industries experienced declining output growth—Leather and Leather Products, Gas Utilities, and Tobacco Manufactures.

Fig. 12 gives U.S. economic growth during the projection period 2004–2030. Again, growth rates will differ substantially among industries with Electrical Machinery exhibiting growth at the very rapid pace of more than 6% per year, comparable to the historical period 1960–2004. Most of the remaining industries, including Non-electrical Machinery, one of the stars of the historical period, will scale back growth. The relatively small Leather industry will reverse the negative growth of the historical period and exceed the economy-wide average of 1.50%.

5. Summary and conclusions

Our first and most important conclusion is that future supply and demand for labor in the U.S. economy will be driven by demography and technology. The supply side of the labor market will be dominated by the slowdown in the growth of the working age population, partly offset by continuing increases in the quality of labor input due to rising average levels of educational attainment and experience. From 1960 to 1990 the participation rate of the working age population increased fairly steadily as more women joined men as participants in the labor market. No such increases in labor force participation are in prospect for our projection period 2004–2030.

The widely discussed aging of the labor force is reflected in the slowing growth of the working age population, relative to the total population. The working age population will continue to expand more rapidly than the population as a whole and participation rates will decline very slowly. However, the slowdown in the growth of the time endowment will reduce the growth rate of the U.S. economy very substantially. This will be reinforced by the decline in investment and growth of capital input than will accompany slow growth of labor supply. It is important to keep in mind that in the neo-classical theory of economic growth embodied in IGEM, the growth of capital input is endogenous and is equal to the growth of output in the long run.[10]

Finally, future growth of productivity will remains robust, despite waves of technological pessimism that sometimes accompany cyclical downturns. Rapid changes in technology will continue to be concentrated in the industries that produce information technology equipment and software, led by Electrical Machinery, the industry that includes electronic components like semiconductors. This industry has had very rapid growth of total factor productivity or output per unit of unit, throughout the historical period 1960–2004. We project that this will continue for the next quarter century although the specific form of the underlying changes in technology will undergo the same dramatic evolution as in the recent past.

[10] Jorgenson, Ho and Stiroh (2007) have pointed out the implications of this fact for growth in an intermediate run of 10 years.

At the level of individual industries the demand for labor depends not only on the growth of output and the substitution of capital input for labor input, but also on the character of technical change. We have emphasized the wide variations in rates of productivity growth among industries. However, labor demand at the industry level is also strongly affected by biases of technical change. We have focused attention in labor-saving and labor-using biases for each of the 35 industries in IGEM. We have assessed the importance of these biases during the historical period 1960–2004 and projected the biases for 2004–2030. Part of the growth of labor input in industries like Instruments, Tobacco, Coal Mining, and Communications will be due to ongoing labor-using biases.

In summary, potential growth of the U.S. economy will be slowing considerably and monetary policy will have to adapt to the new environment. The changes we have projected embody many features of the future labor market that are well known to economists and monetary policy-makers—slowing population growth, particularly for the working age population, and declining growth in labor quality. We have quantified these factors by relying on official population projections for the Bureau of the Census and our own estimates of labor quality growth. This has enabled us to characterize the future growth of labor supply with some precision.

The future growth of the U.S. economy depends on the contribution of labor input, that is, the growth rate of labor input multiplied by the labor share of output. However, future growth also depends on the rate of growth of total factor productivity and the contribution of capital input. In the neo-classical theory of growth embodied in IGEM, the contribution of capital input, the growth rate of capital input multiplied by the capital share, is endogenous. To a reasonable approximation growth rates of output and capital input must converge in the long run. The only component of the sources of growth not yet accounted for is productivity growth.

We have projected future productivity growth on the basis of the historical data on productivity growth constructed by Jorgenson, Ho, Samuels, and Stiroh (2007). We have augmented this description of future changes in technology at the level of individual industries by estimating and projecting labor-saving and labor-using biases of technical change. This enables us to conclude that future productivity growth during the next quarter century will be substantially less than productivity growth during our historical period 1960–2004. This completes our analysis of labor demand and its distribution by industry.

Economists and policy-makers, especially in the Federal Reserve System, have made important contributions to our present understanding of the role of technology in the evolution of labor demand and the growth of the U.S. economy.[11] The remaining challenge will be to build the new understanding of technology and the sources of economic growth into the framework for the conduct of monetary policy. This new policy framework can be erected on the solid foundation provided by projections of future demographic change. The new framework will be an important addition to the Federal Reserve's highly successful policy structure for understanding and mitigating the impact of the business cycle.

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[11] An excellent summary of this research is provided by Oliner, Sichel, and Stiroh (2007). The implications for monetary policy are discussed in Chairman Ben Bernanke's in his 31 August 2006, speech on "Productivity" http://www.federalreserve.gov/BOARDDOCS/Speeches/2006/20060831/default.htm.

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